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70 MW PLASMA WIND TUNNEL UP-GRADES FOR ESA AURORA TPS TESTING

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Contents of the presentation

- SCIROCCO description
- Objectives of AURORA project
- Modifications on the facility
- Consequences on the performances
- Conclusions and next phases

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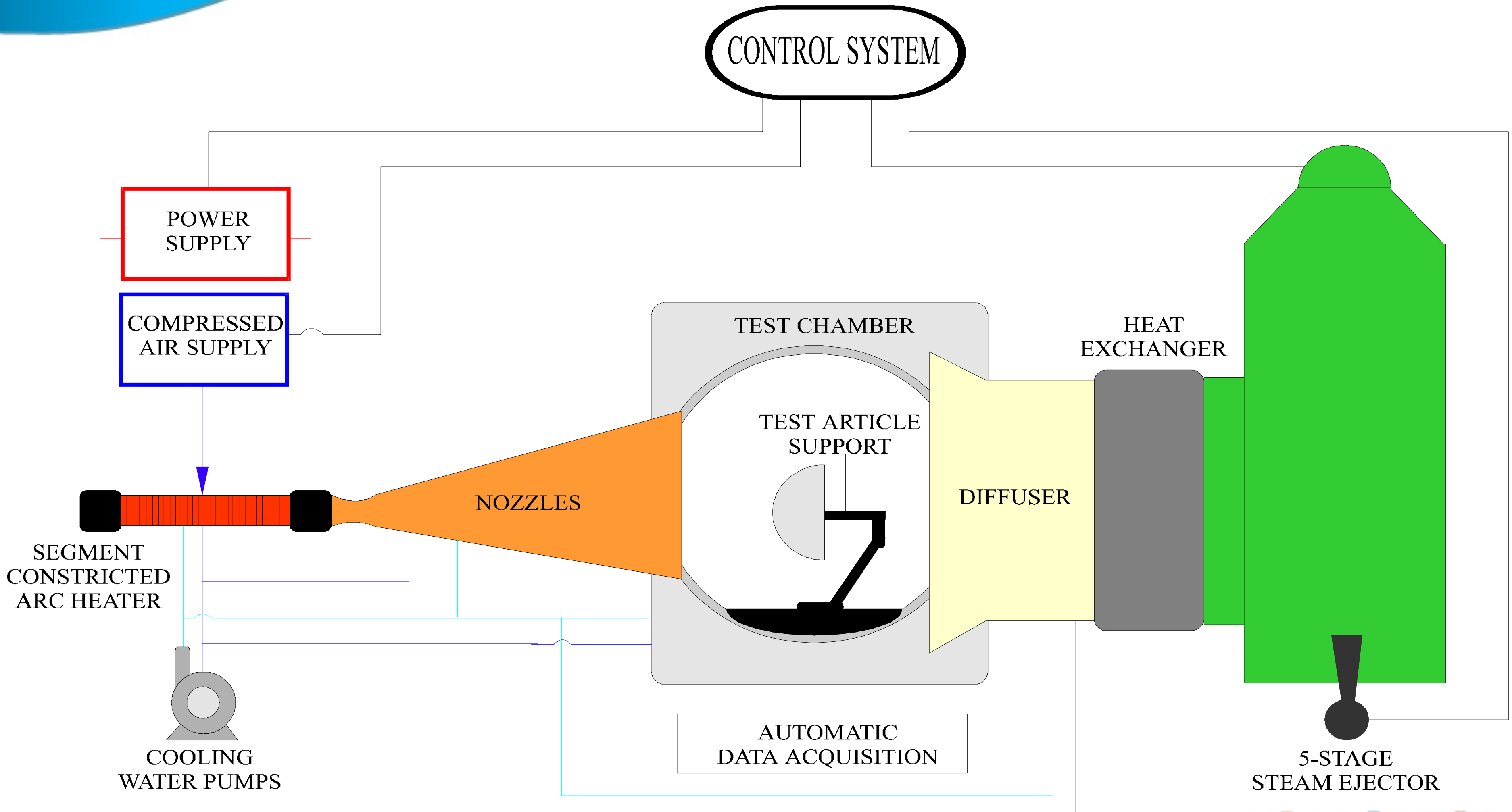
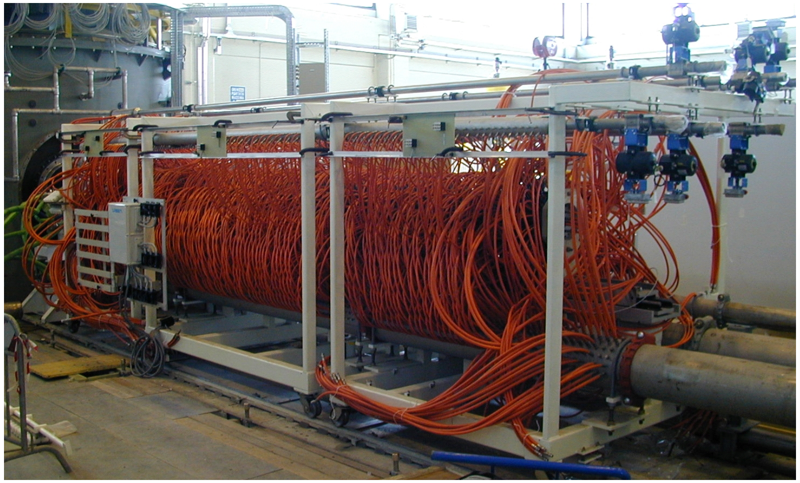
Facility schema



Main facility components

70 MW Power
Length of 5.5 m
Max current 9000 Amperes
Max voltage 30000 Volts



Twelve steam ejectors
on three parallel lines
Total steam power of 80 MW
hydrocarbon energy

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Objectives of feasibility study

WP 1100:

Mars atmospheric entry

WP 1200:

Earth super-orbital re-entry

WP

Task 1: Modifications on the facility

- Description of the modifications
- Plan of the modifications
- Consequences on the performances
- Schedule for the upgrade
- Cost of the modifications

Task 2: Instrumentation required

- Definition of the necessary instrumentation
- Plans of the measurement techniques
- Schedule for the instrumentation
- Cost of the instrumentation

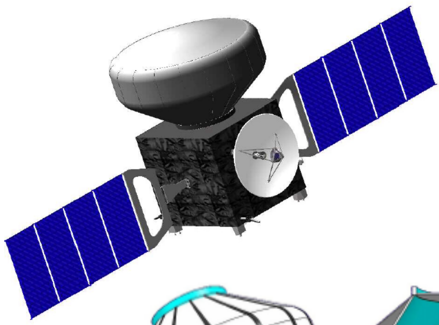
Task 3: Test plan

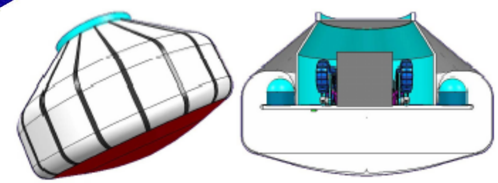
- Number of tests
- Parameters measured
- Test conditions
- Measurement techniques and post-treatment
- Schedule and cost of the test campaign

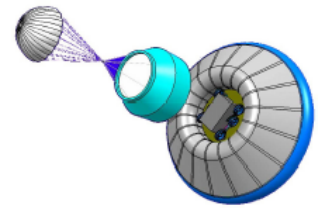
Mars atmospheric entry (1)

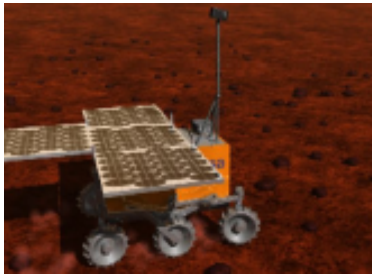
Requirements:

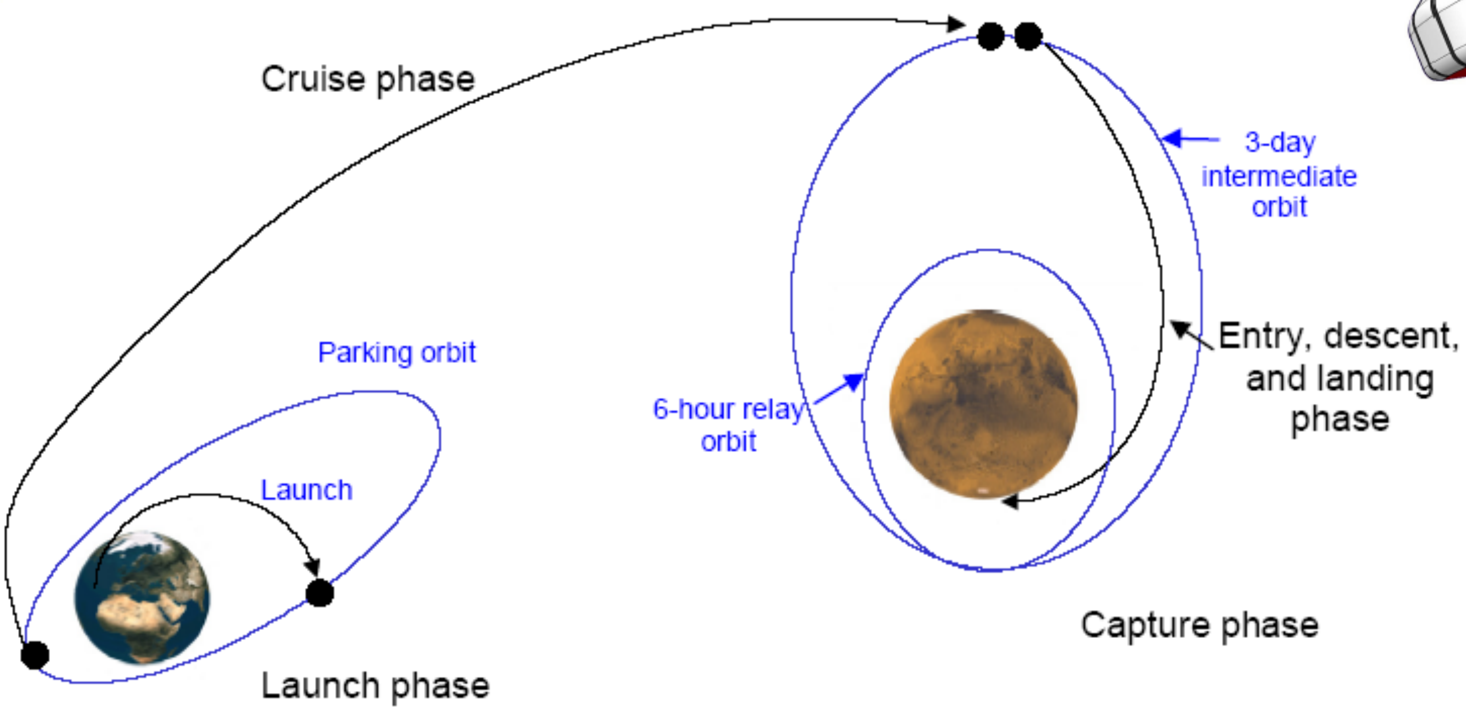
ESA ExoMars mission



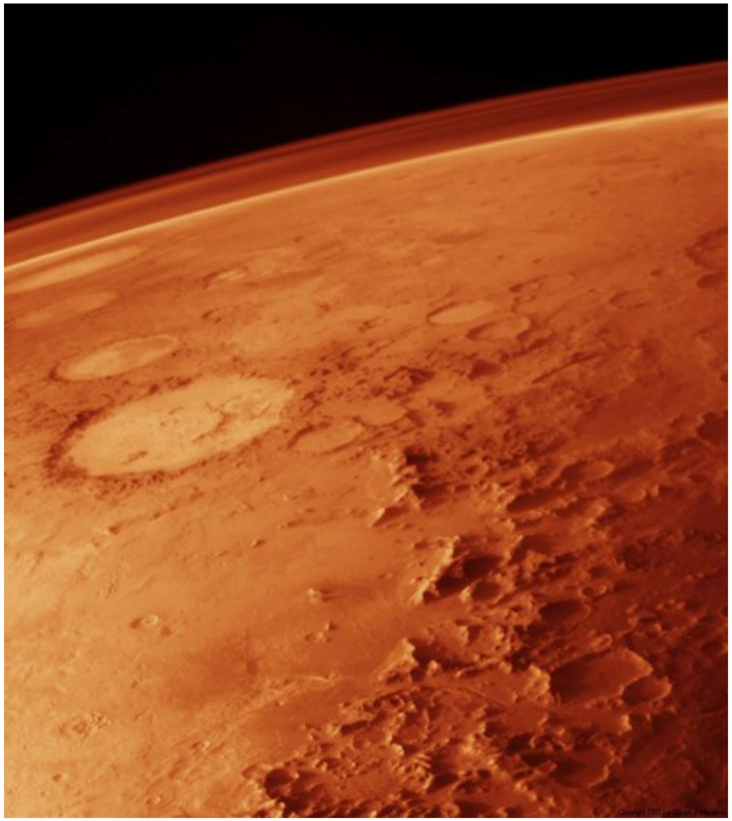




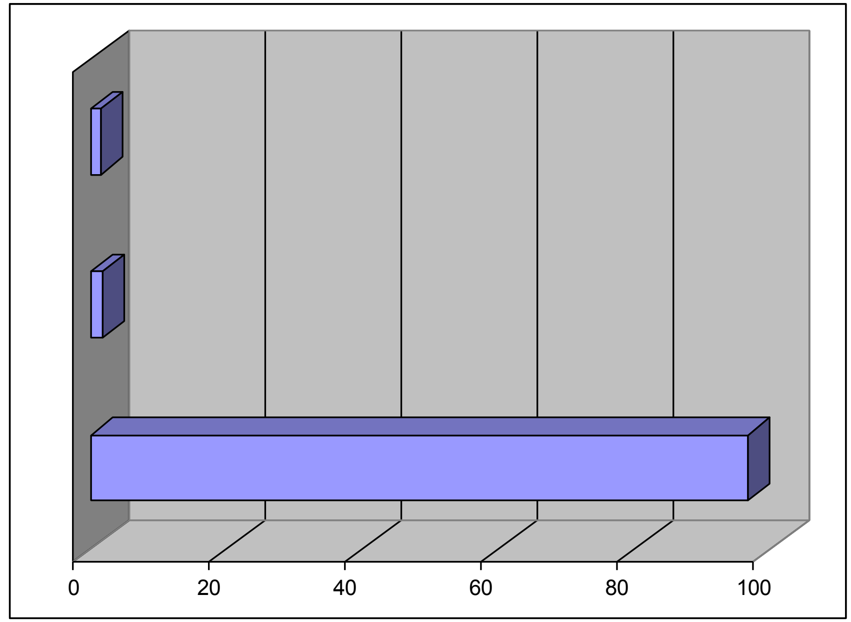




Atmosphere of Mars



Ar	1.5 %
N_2	1.7 %
CO_2	96.8 %



Modifications on SCIROCCO (1)

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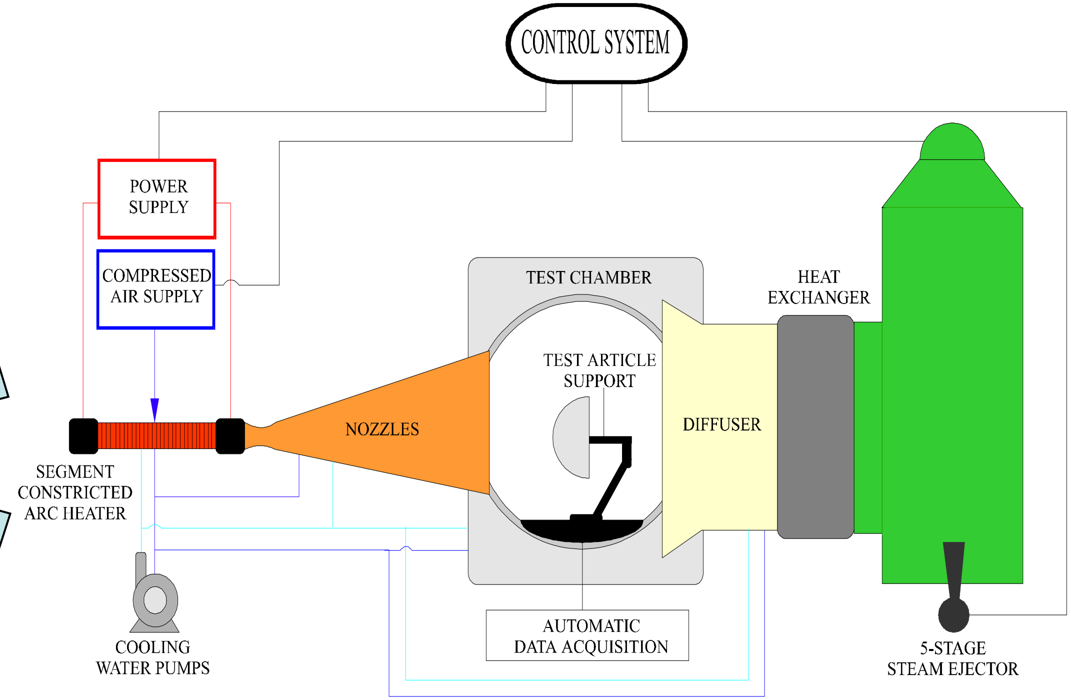
CO_2 (max 2 Kg/s)

N_2 (max 35 g/s)



Modifications on SCIROCCO (2)

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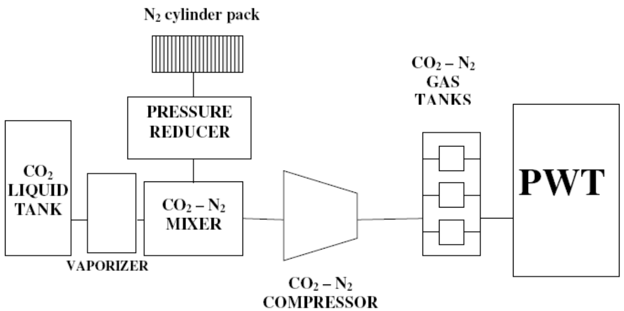
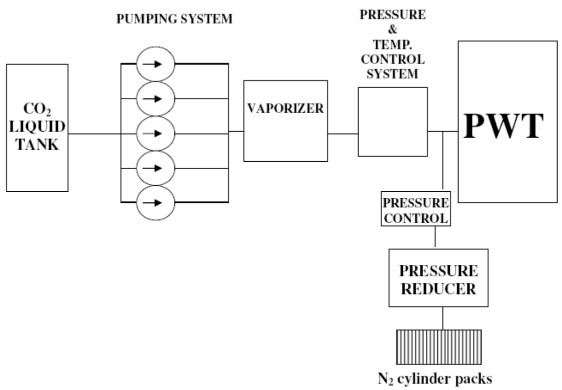
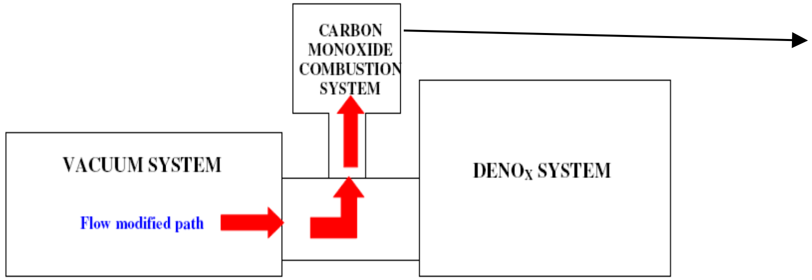
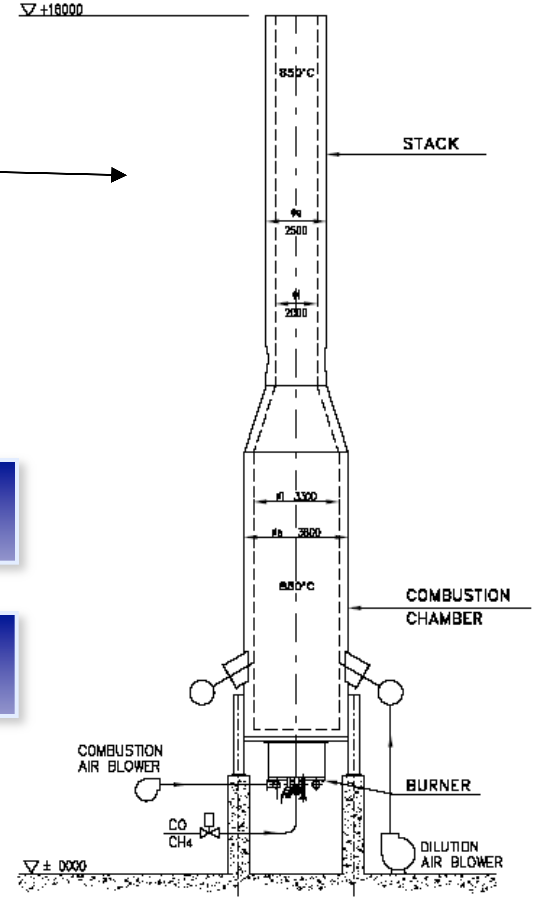
Technical solutions for the $CO_2 - N_2$ gas system





Solutions for the CO gas system





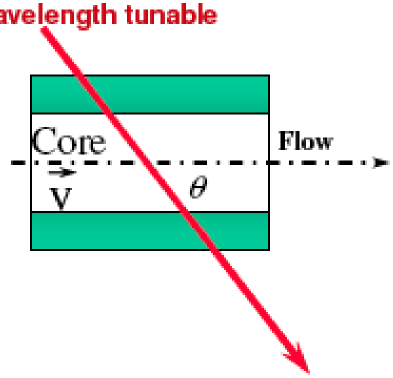
13.2 MW CO nominal

1 MW support methane

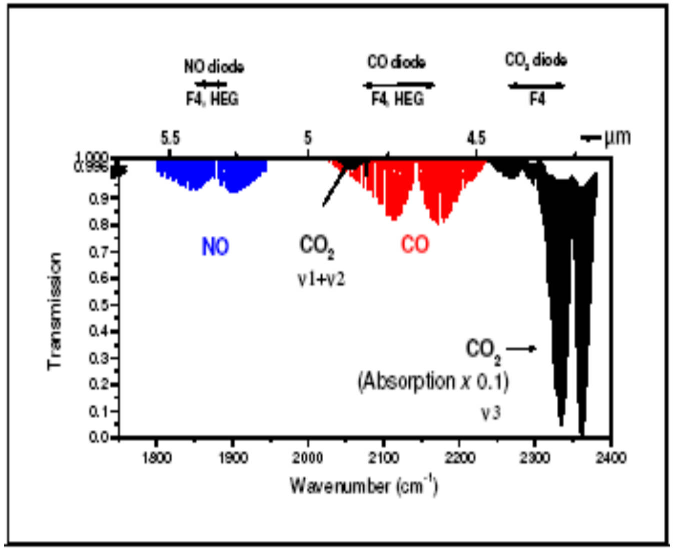
Compressed air piping electrically heat traced

Instrumentation (1)

Diode Laser Absorption Spectroscopy (DLAS)

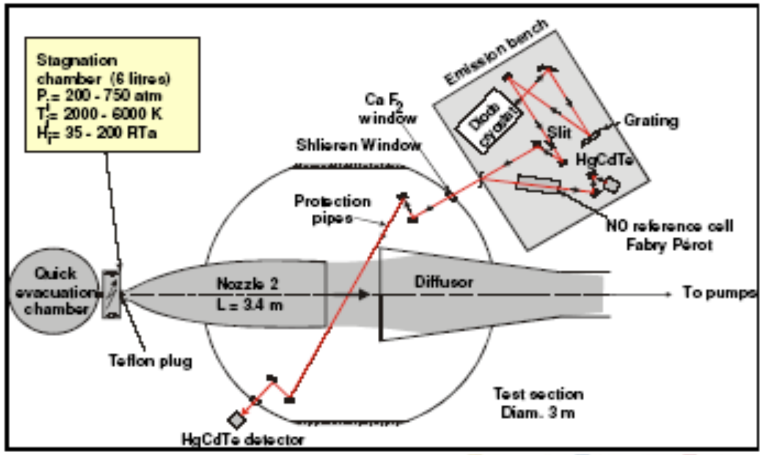


- Velocity $\Delta\sigma_x = \sigma_x \dfrac{V}{c}\cos(\theta)$
- Temperature (translation)
- Species densities



Spectral coverage of some laser diodes

Typical Diode Laser Absorption Spectroscopy experimental setup



Air and CO_2 properties (1)

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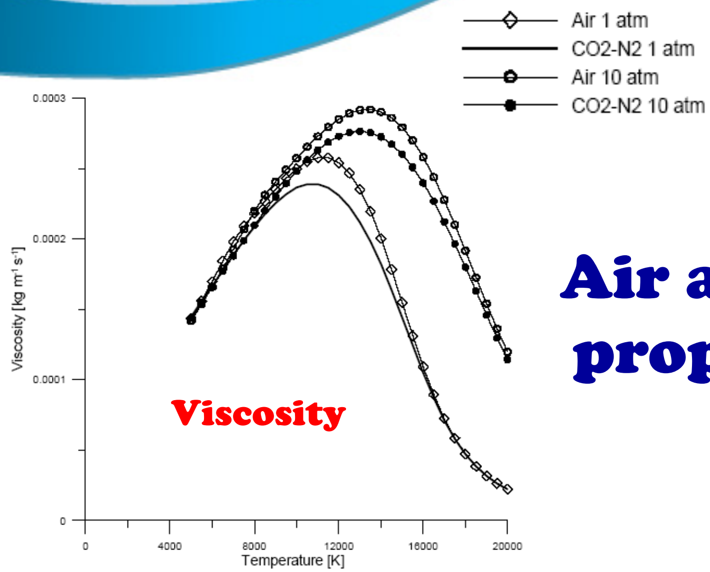
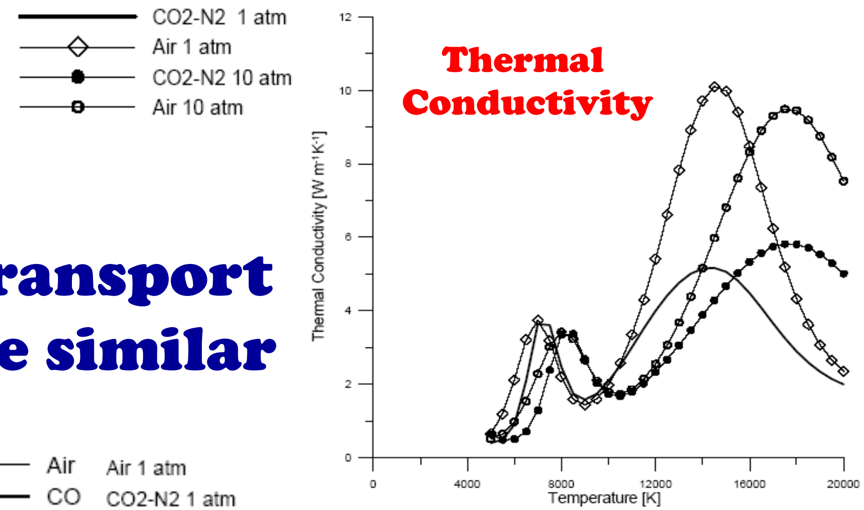
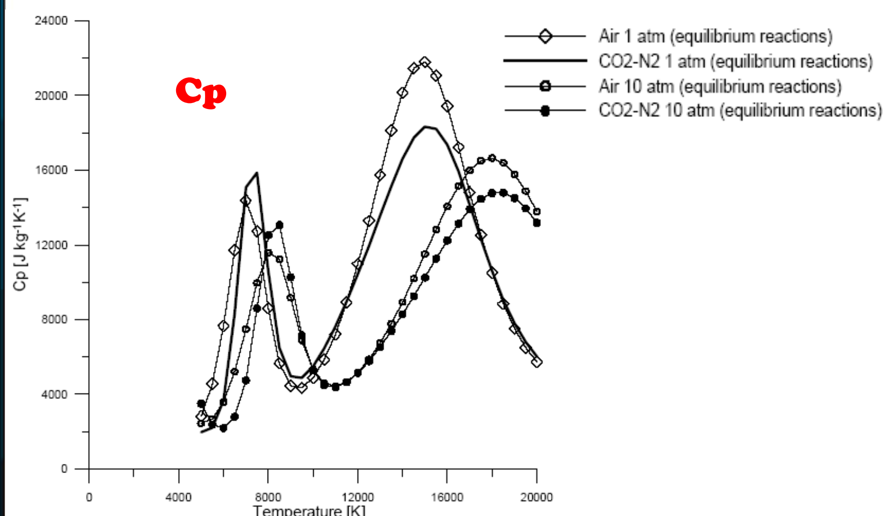
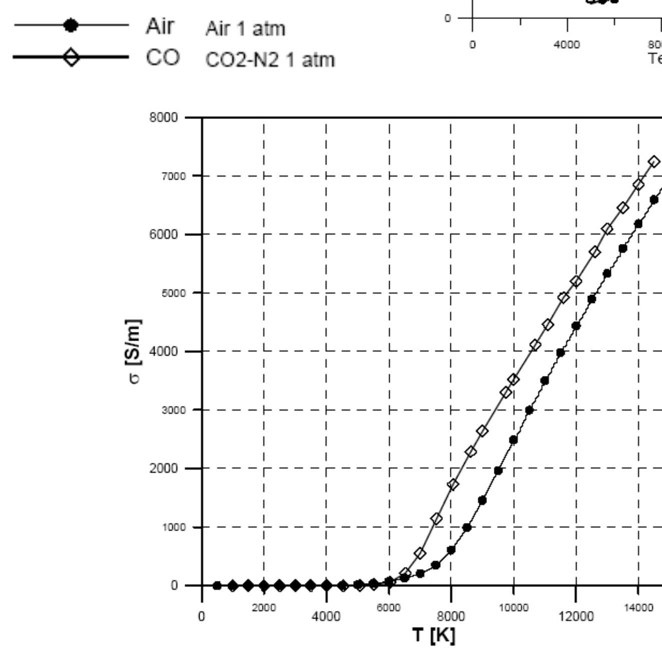


Air and CO_2 transport properties are similar



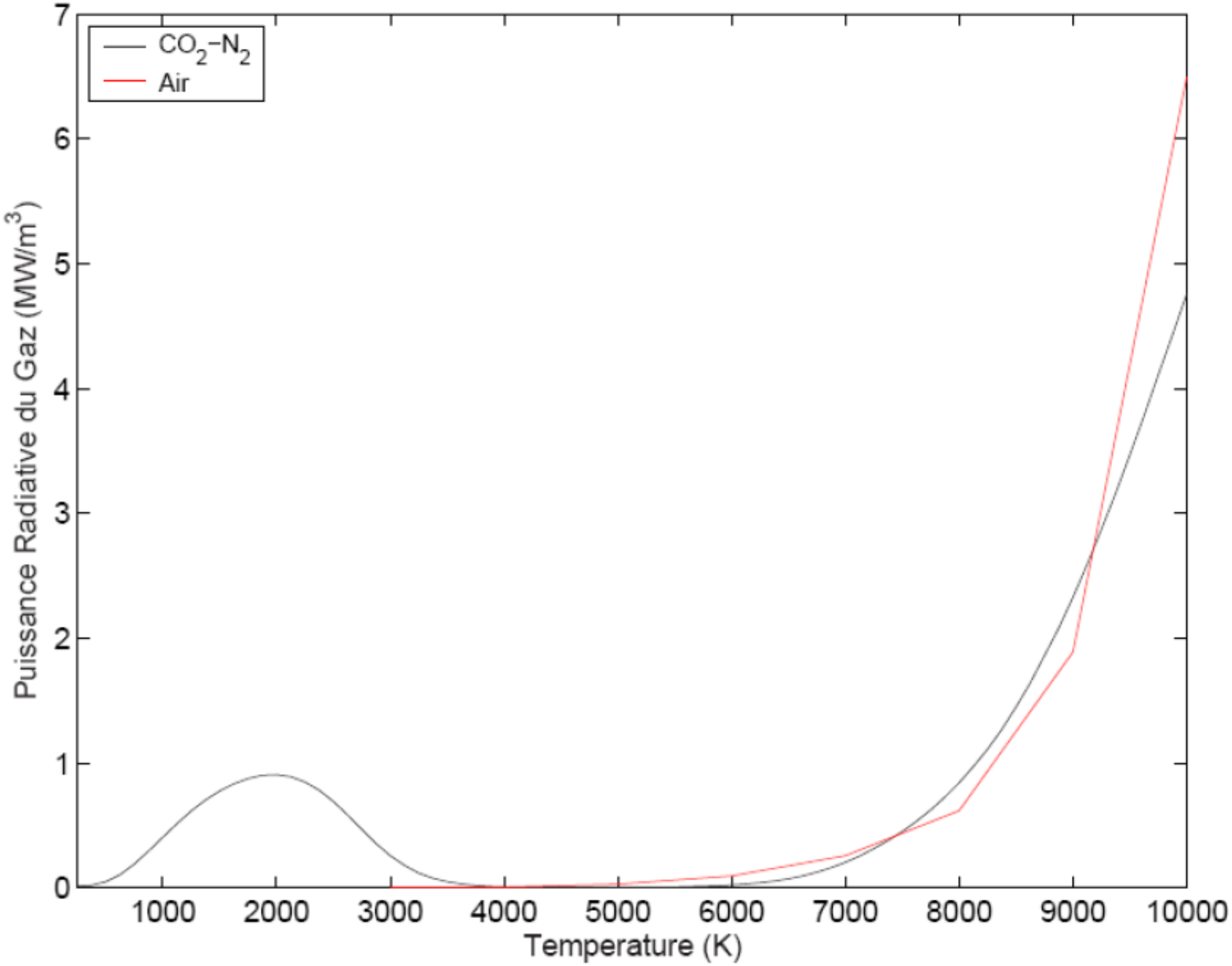




Electrical Conductivity

Air and CO_2 properties (2)

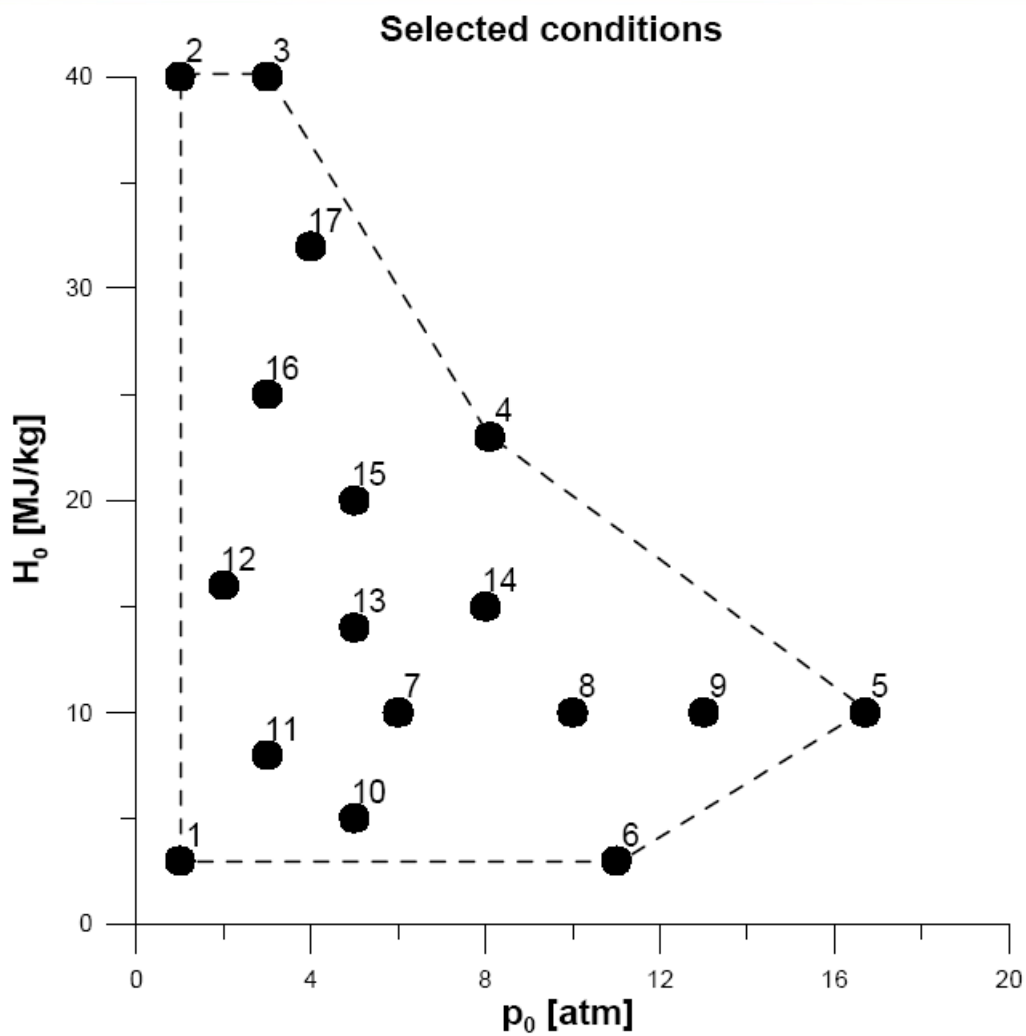
Radiation properties



CFD simulations (1)

The same specific total enthalpies and total pressures as in air have been assumed at the SCIROCCO nozzle inlet

The objective is to evaluate the stagnation point pressure and the stagnation point heat flux on a hemispherical fully catalytic probe (radius 5 cm). The nozzle F is considered, with an exit section of 1.95 m diameter



Fluid – Dynamic model

- A nine – species (Ar, CO_2, CO, C, O, O_2, NO, N, N_2) gas model is taken into account to simulate Mars atmosphere.

- Each species of the mixture is assumed to behave as a thermally perfect gas. Contributions to species energy come from translational – rotational, vibrational – electronic and chemical energies. Different vibrational temperature are used for each polyatomic species composing the mixture. A harmonic oscillator model is used to describe vibrational energies.

- The rate at which vibrational energies relax towards translational energies is assumed to behave according to the Landau – Teller model. The vibrational relaxation time is derived from the Millikan – White formula, with Park correction for high temperatures. Removal of vibrational energy by means of dissociation and effects of vibration on dissociation are not taken into account.

- Electronic energies are assumed in equilibrium at the corresponding vibrational temperatures.

- Chemical kinetic model is taken from Park ('96). Only the relevant reactions are taken into account.

Numerical solver

- The FLUENT code solves the finite volume formulation of the Navier – Stokes equations coupled to the thermo – chemical equations.

- Convective fluxes are computed according to Roe's Flux Difference Splitting scheme. Advection Upstream Splitting Scheme AUSM is also available. Up to 3rd order spatial accuracy may be achieved by a MUSCL (Monotone Upstream Schemes for Conservation Laws) TVD (Total Variation Diminishing) formulation.

- Diffusive fluxes are computed by the classic, second order accurate, centered formulation.

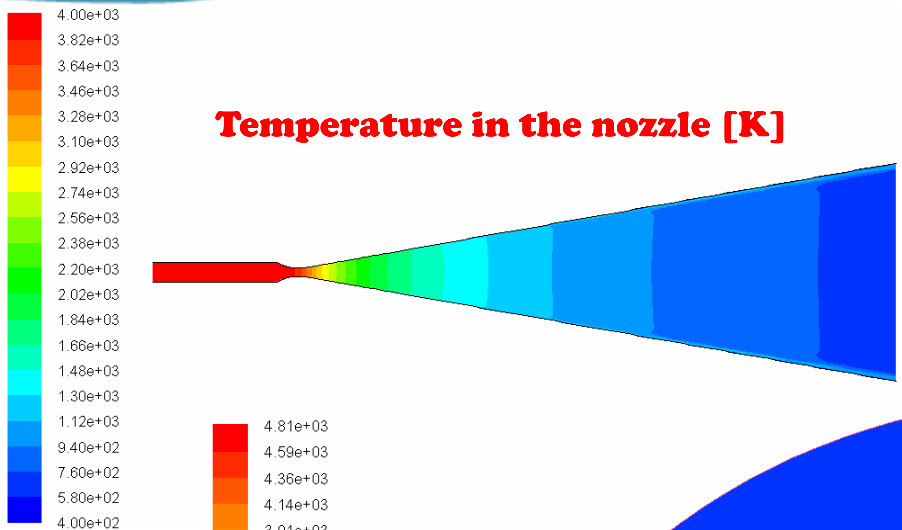
- Integration of the equations is performed implicit in time, until steady state is achieved, by means of an Algebraic Multigrid Linear solver.

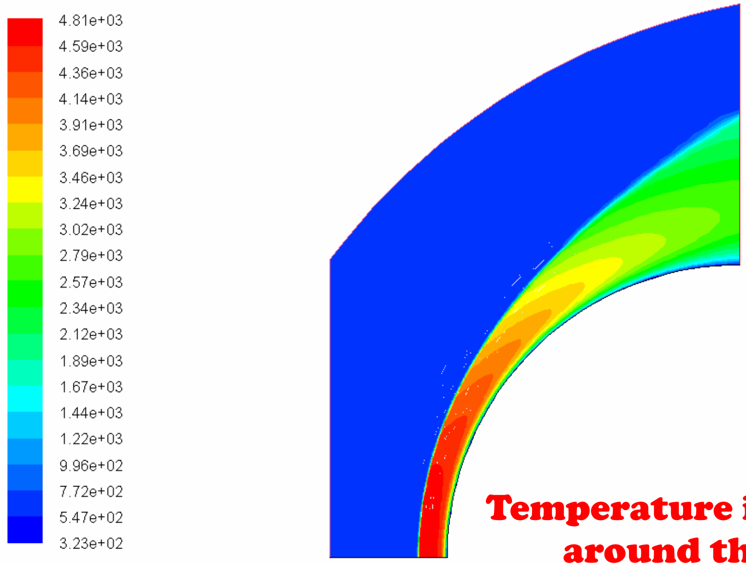
- The commercial solver has been used in this work in combination with a number of "ad hoc" developed user defined functions to model hypersonic flows in chemical and vibrational nonequilibrium.

CFD simulations (2)

Results

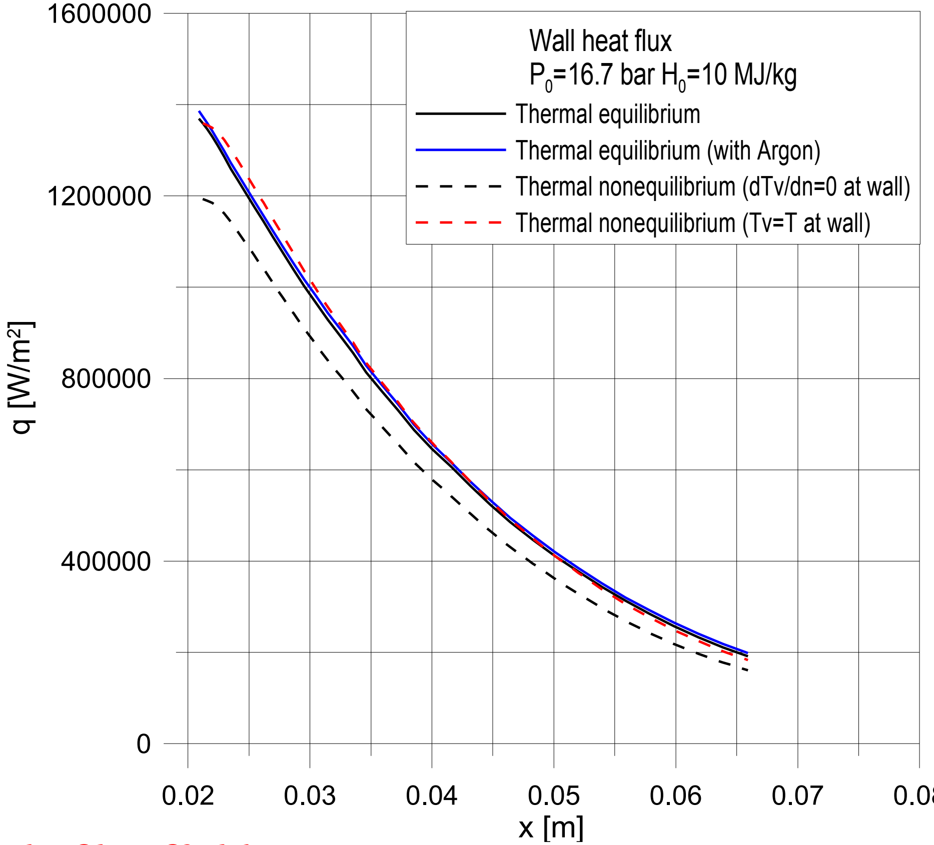
Temperature in the nozzle [K]



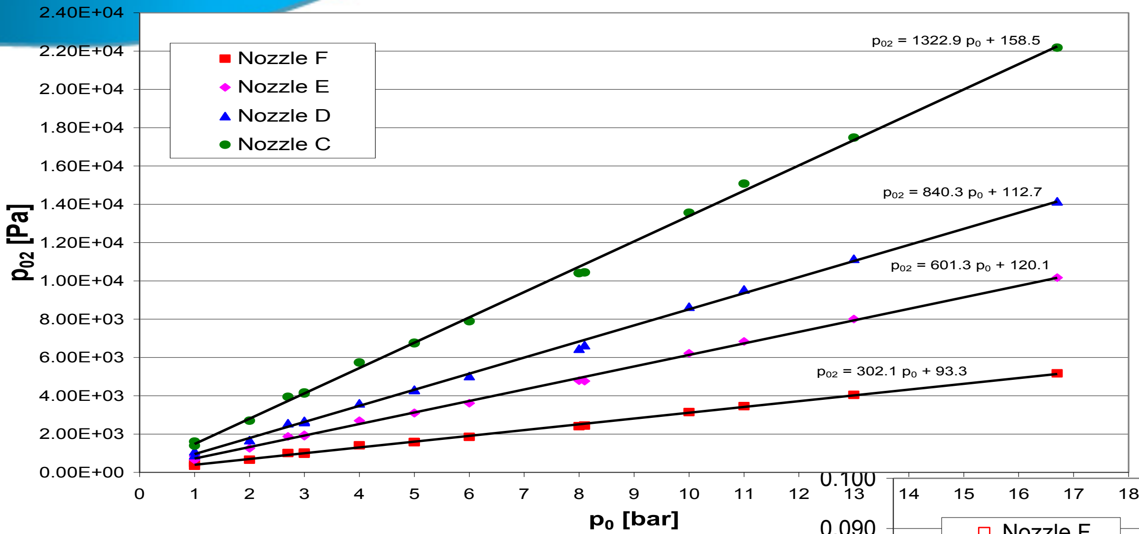


Temperature in the flowfield around the probe [K]

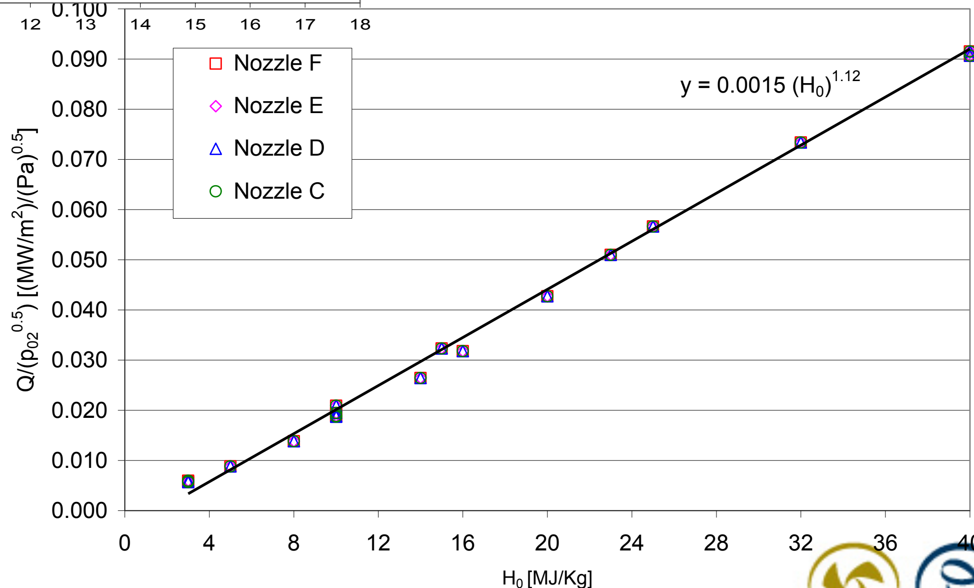
Probe surface heat flux [W/m²]



CFD simulations (3)



p_{02} vs p_0



Stagnation point heat flux

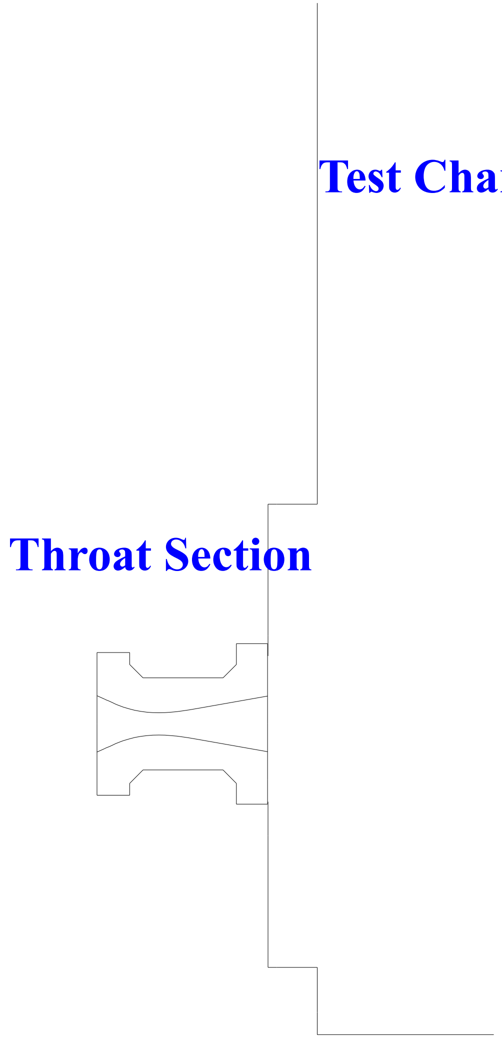
Earth super-orbital re-entry

Return to Earth

- Velocity ~ 11/12 [km/s]
- Stagnation pressure ~ 10^5 [Pa]
- Heat flux ~ 10^7 [W/m^2]

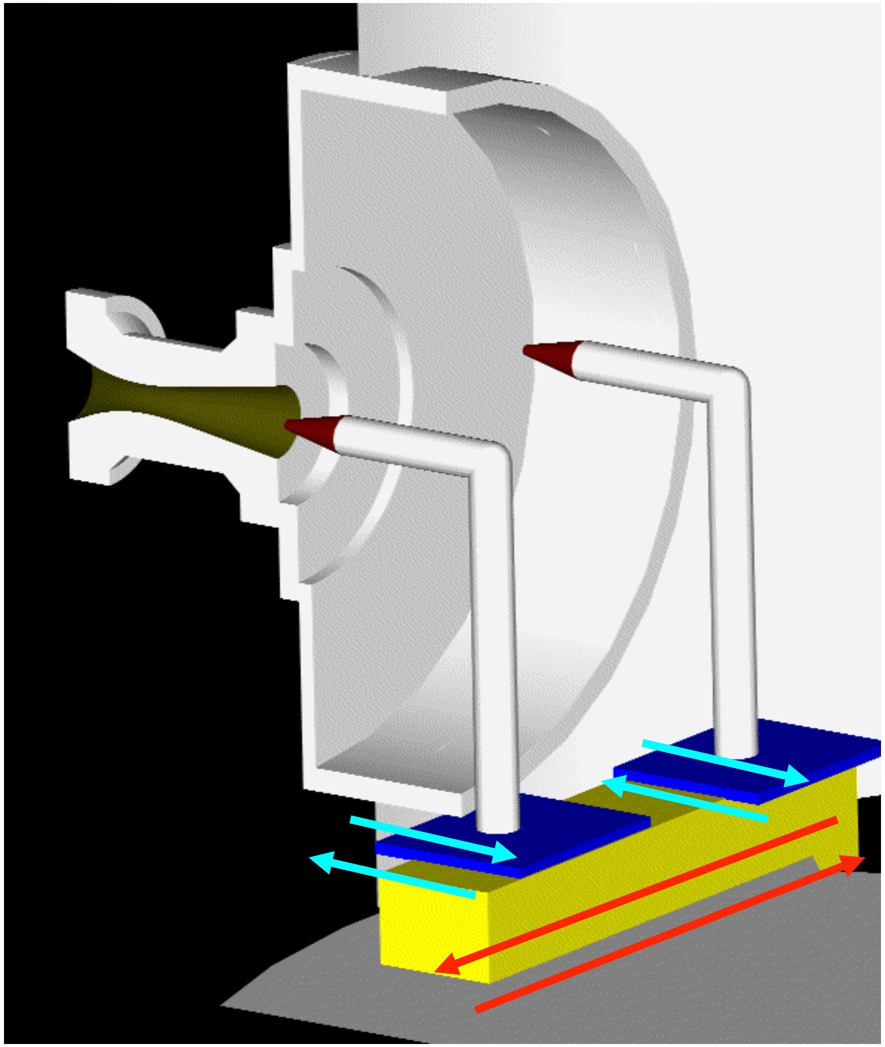
Modification on SCIROCCO (1)

Usage of the only throat section to reach the super-orbital Earth re-entry conditions in terms of stagnation pressure and stagnation heat flux



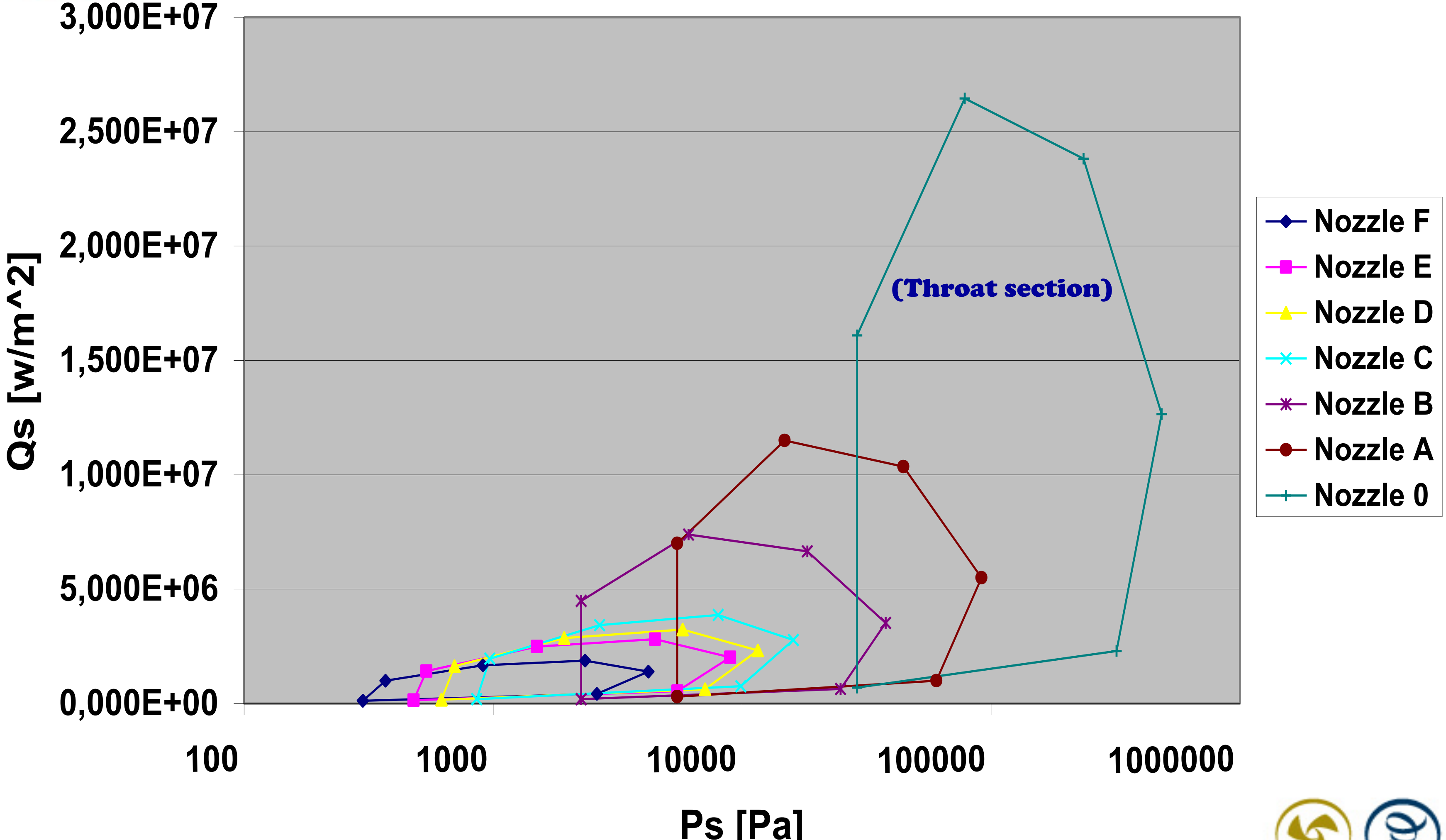
Modification on SCIROCCO (2)

A new Model Support System is necessary to keep the model at the necessary distance from the throat section in order to reach the requirements

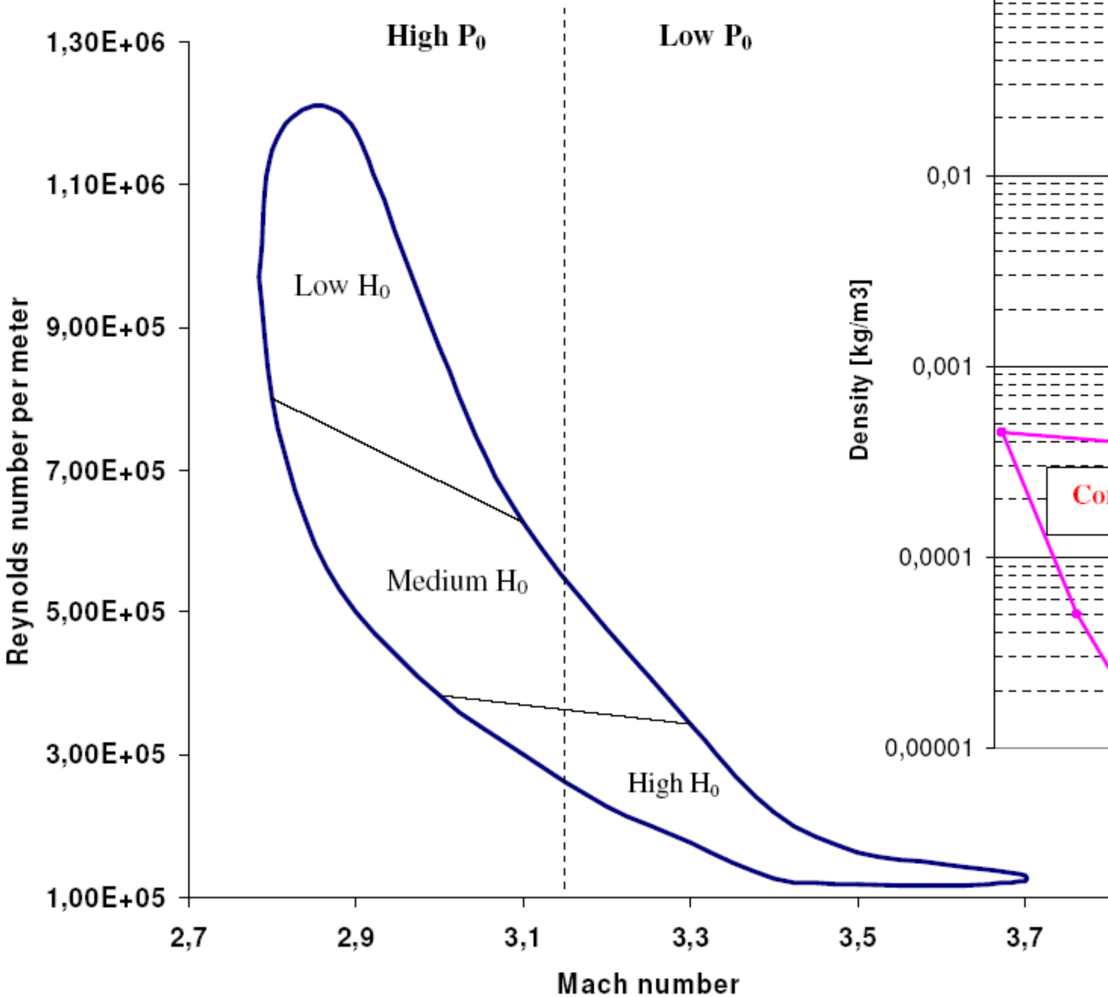


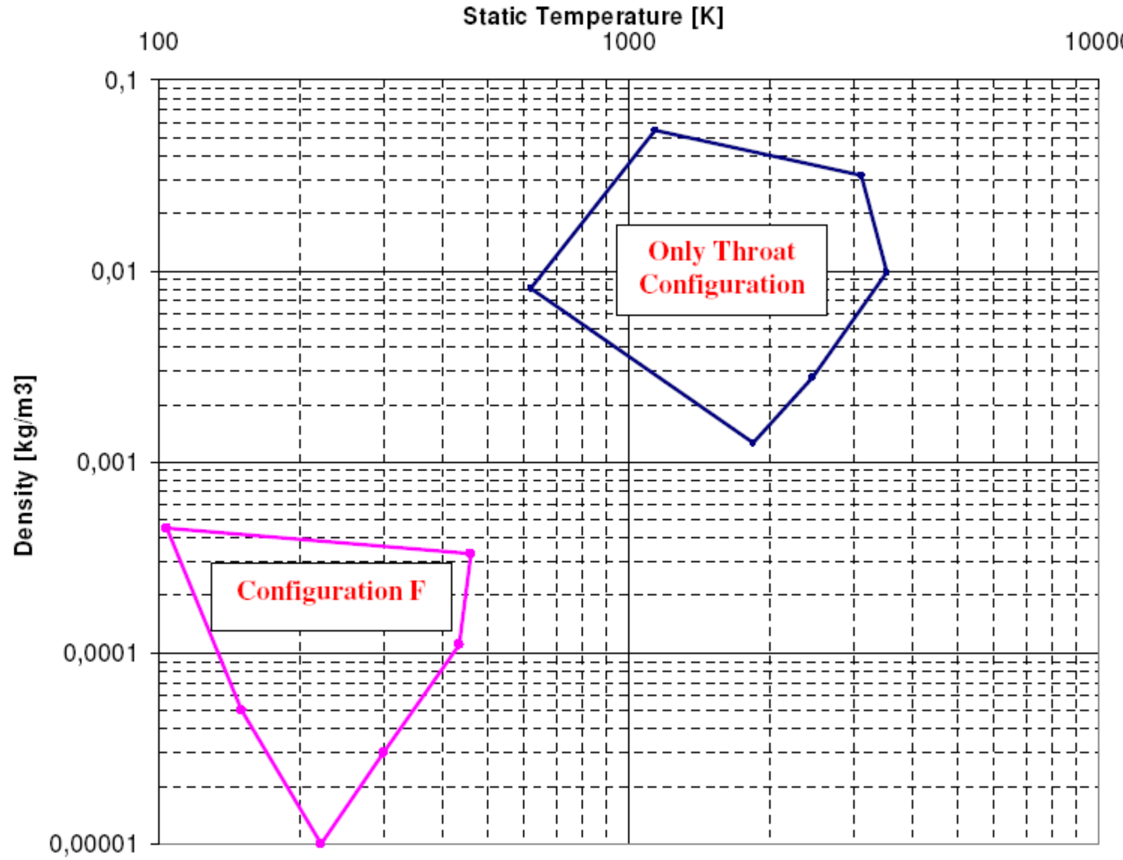
New performances (1)

Comparisons: Heat flux vs p_{02} for all nozzle configurations



New performances (2)





Conclusions

- The facility modifications requested in order to have Scirocco Plasma Wind Tunnel ready for Aurora ESA Program are presented and discussed
- Both goals, i.e. to simulate the Mars entry conditions and the Earth super-orbital re-entry conditions, are achievable through a set of engineering modifications and solutions (impacts, costs and time schedule estimated)
- The ESA Agency is evaluating the feasibility study. A decision for the following operative phase resulting in the realization of the modification judged necessary and mandatory is expected within short time.